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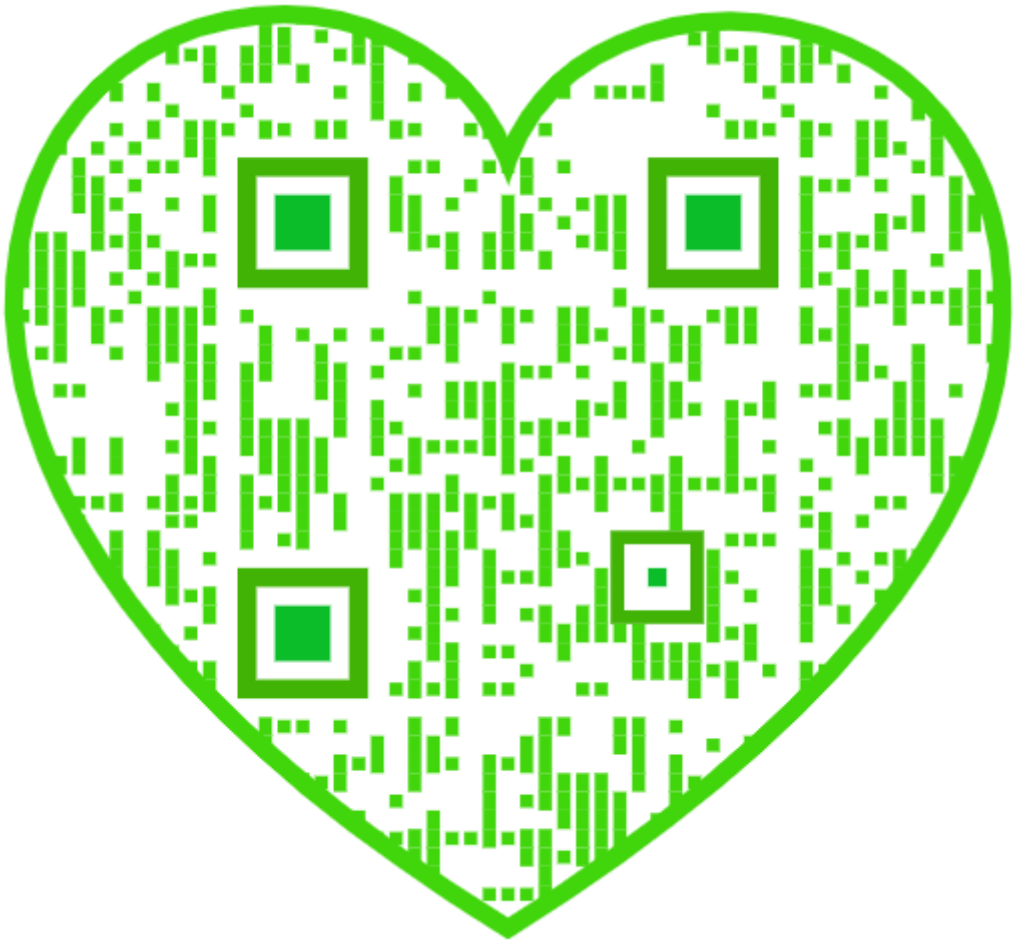

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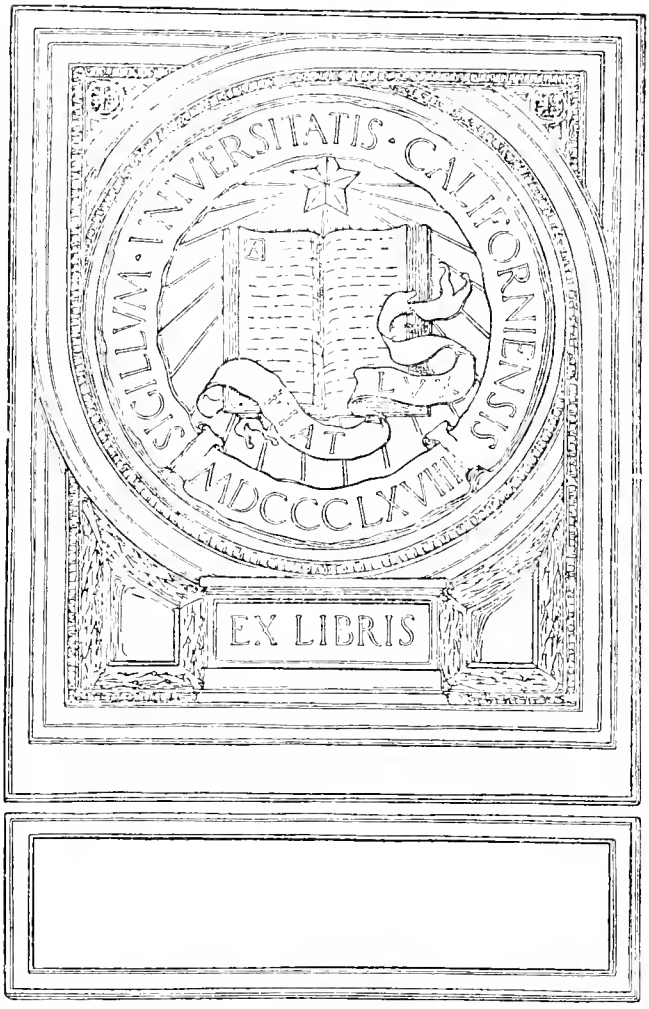

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The Relative Legibility of Different Faces of Printing Types

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THE RELATIVE LEGIBILITY OF DIFFERENT FACES OF PRINTING TYPES

By Barbara Elizabeth Roethlein, A.M., Clark University

Communicated by John Wallace Baird

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I. INTRODUCTORY

The aim of the investigation which is here reported was to determine the relative ease or difficulty with which various 'faces'[1] or forms of printed letters can be read; and to discover what relationship obtains between legibility and certain definite modifications of 'face.' A number of typically different faces of type were selected for investigation; and our experimental procedure consisted essentially in determining to what extent the legibility of each face was affected —both when the letters were presented in isolation and in groups—by the introduction of unfavorable conditions for reading. The present paper will deal only with 'type-faces'; the question of the part which is played by printing papers and printing inks will be discussed in a later paper.

[1] The term 'face' is employed here and throughout this paper in the sense in which it has come to be used by printers and type-founders. It is customary to group the numerous variants of letter-form into families,—Caslon, Cheltenham, Jenson, Ronaldson, etc.,—and to speak of each family or typical variant from the common letter-form as a 'face.'

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At the time when the art of printing from individual or moveable types was first introduced, the forms of the letters of the alphabet were few in number and exceedingly crude in design. The use of 'black letter' had been popularized by generations of manuscript writers; and the early printers were content to appropriate those letter-forms which they found to be in current use. But within a few decades designers and draughtsmen set themselves the task of simplifying and improving the existing forms of letters; and, indeed, it seems probable that the Roman 'faces' were introduced about the year 1465, and the Italic 'faces' some thirty-five years later. The ingenuity of many generations of mediaeval and modern designers has produced a multitude of variants of letter-forms, many of which are familiar to every reader (a, a, a, a, a; g, g, g, g, g). Hundreds of different 'faces' of type have been designed and put upon the market; and while it is true that certain of these 'faces' are employed only for purposes of ornamentation and display, yet an enormous variety of letter-forms is to be found in our books and magazines. Every reader has observed that all of these variants of letter-form are not equally legible—an observation which raises the theoretical question: What are the factors upon which legibility depends? And the practical question: How should one proceed if one set out to improve the legibility of printed letters?

II. HISTORICAL

Psychologists have been engaged these many years in an investigation of the act of reading in its various aspects. But there is a singular dearth in the literature so far as the specific topic of the present investigation is concerned.

More than forty years ago, Exner (17) and Baxt (2) undertook to measure the brief period of time which is necessary for the perception of visual objects (letters, words); and in 1885 Cattell (6, 7, 8) continued the investigation of the same problem. Baxt had reported that, under his most favorable conditions of illumination, it was possible to read two or three letters of a total group of seven when

they were exposed for one one-hundredth of a second. Cattell devised a falling-screen apparatus which enabled him to vary and to measure his exposure-times. He found that the differences in the times which are necessary for the recognition of isolated letters, whether upper case or lower case,[2] whether Latin or German, are of negligible magnitude. When the exposure-time was very brief, it was found that the letters were not always read correctly. A record of the percentage of correct readings of the various letters, when presented under constant and uniform conditions, enabled Cattell to determine the relative legibility of the letters. The order of legibility (descending) was found to be: W Z M D H K N X A Y O G L Q I S C T R P B V F U J E and d k m q h b p w u l j t v z r o f n a x y e i g c s,—W being read correctly in 89 per cent. of the trials, E in 23 per cent.; d in 87, and s in 28 per cent.

Sanford (35) employed a similar method, but obtained a somewhat different result; his order was (for Snellen type, lower case):

m w d q v y j p k f b l i g h g r x t o u a n e s c z

Sanford also determined the relative legibility of the same letters by a distance method, and obtained the following result:

w m q p v y j f h r d g k b x l n u a t i z o c s e

Sanford also tested alphabets representing two other letter-forms,—a modern face, and a bold oldstyle face. The modern face letters were recognized in the following order (distance test):

d p q m y k n w o g v x h b j l i a t u z r s c f e

The oldstyle letters fell into the following order (tested by the method of brief exposure):

m w p q v y k b d j r l o n i g h u a t f s x z c e

Finzi (18) employed the method of brief exposure, presenting a group of nine letters at each exposure. From

[2] The term 'upper case' will be used throughout to designate the capital letters, and 'lower case' to designate the small letters.

the percentage of misreadings of each letter he computed the order of legibility as follows:
P U A Q X T D S E W M V Y Z H C N F L R G B K O I,
the percentage of errors ranging between .8 for P, and 7.8 for I. The particular type or letter-form which Finzi employed is not specified in his paper.

Griffing and Franz (21) investigated the influence of size and form of letter upon legibility. Their experiments comprised a fourfold test: What is the difference in the rapidity with which small print and large print can be read (five-point and twelve-point, both Roman)? How many letters of each of these two sizes can be read in a single brief exposure? How long must letters of each size be exposed in order to insure their correct reading? What intensity of illumination is necessary for the recognition of letters of various forms and sizes,—Roman letters, .8 mm. and 1.6 mm. high; Gothic letters, .9, 1.6, 3.1, and 6.0 mm. high? These investigators found that their larger types were, in every instance, more legible than their smaller types; and that Gothic letters were more legible than Roman letters.

Besides these experiments which have just been described, numerous attempts have been made to investigate other factors which have to do with the act of reading. The nature and the extent of the eye-movements by means of which the reader follows the printed line have been examined and measured by Huey (22, 23, 24), Dodge (13, 14, 15), Erdmann and Dodge (16), Dearborn (10), and others. It has been established that the movement of the reader's eyes does not proceed gradually and continuously across the page, in any such fashion as, for example, a meteor moves across the sky. Typical eye-movements consist of a succession of alternate leaps and pauses; nor is the movement always in a forward direction, because it frequently happens that one's eye-movement proceeds backward, i.e., to the left, from an intermediate fixation-point. The number of pauses may vary from two to seven in a line whose length is twenty centimeters; but the usual distance between successive fixation points or pauses is approximately 2 cm. It seems

probable that no words are seen while the eyes are in movement; and that the act of reading a printed line consists of a series of interrupted glimpses, during each of which one reads a small section which extends to the right and to the left of the fixation-point.

This discovery makes it seem probable that a considerable part of the printed line is imaged, not upon the fovea, but upon para-foveal regions of the retina. And the capacity of these paracentral regions to distinguish the forms of letters becomes an important topic for investigation. This problem has, indeed, been attacked by Kirschmann (28) and by Dockeray (12); but further investigation is needed before one can make any definite statement regarding the legibility of letters in indirect vision.

Numerous other investigations of the problems of reading have been made by Babbage (1), Becher (4), Goldscheider and Müller (19), Javal (26, 27), Maire (31), Messmer (32), Pillsbury (33), Quantz (34), Schumann (37), and Zeitler (40); but it seems more appropriate to discuss their results in connection with our own findings, than to summarize them in this section.

III. EXPERIMENTAL

A. ISOLATED LETTERS

a. Materials and Apparatus

The materials which were employed in the present investigation were sheets of printed letters; and the apparatus consisted of a mechanism by means of which these letters could be presented at a variable distance from the observer.

When the investigation was first undertaken, we made a careful examination of the various faces of type which are listed in the sample-books of the American Type Founders Company.[3] We selected fifty faces of type,—comprising

[3] The author is indebted to the American Typefounders Company, Jersey City, for a liberal donation of types and of prints, without which the investigation would have been impossible. Especial thanks are due to Messrs. Frank B. Berry, L. B. Benton and Morris Benton of that firm for valuable suggestions regarding letter-forms and

some thirty ordinary faces, together with such variants as italic, bold, condensed, expanded and various combinations of these variants.

In these earlier experiments, it was decided to employ the method of brief exposure; and an apparatus was devised which provided for a succession of exposures, each one one-thousandth of a second in duration. The series of exposures of any given letter was terminated by the depression of a key by the observer; and an automatic counting device recorded the number of exposures which had been necessary for the reading of the letter. For certain technical reasons this apparatus and mode of procedure were abandoned after a number of preliminary experiments had been made; and the distance test was substituted.[4]

The apparatus, by means of which we obtained the results on which this paper is based, consisted of a long bench along which moved a sliding carriage containing the letters to be read. The bench was 440 cm. long and 15 cm. wide. Its proximal end was 78 cm., and its distal end 63 cm. above the floor, so that the observer was able to assume the primary position of regard throughout. The higher end of the bench was provided with a vertical support, which carried a head rest,—the hood of a stereoscope. This device enabled the observer to assume and to maintain a constant position in relation to any point on the scale upon the side of the bench.

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regarding the interpretation of our results. We are also under obligation to Dr. H. L. Koopman, of Brown University, and to Mr. C. Chester Lane of the Harvard Press; Mr. L. D. Evans of the Riverside Press, Cambridge, Mass., has furnished us with valuable data concerning compositors' errors and proof-readers' errors.

[4] It is a well-known fact that concentration of attention has a very pronounced effect upon reaction-time, and that the duration of the reaction varies with variations in degree of concentration. It seemed difficult, even impossible, to maintain the same degree of concentration through thousands of readings of letters; and, in the absence of a control of this exceedingly influential factor, the results of our tachistoscopic experiments seemed wholly unreliable. For this reason the tachistoscope was abandoned, and a method which consisted in presenting the letters at variable distances was substituted.

The carriage which moved along the bench consisted of a box 55 cm. high, 40 cm. wide, and 25 cm. deep. The front of the box had been cut away; and the back consisted of a wooden wall against which the sheet of printed letters was attached and held in place by a sheet of glass. The back wall of the box was illuminated by a number of electric lamps, so arranged that the whole surface of the sheet of letters was uniformly illuminated. To the side of the carriage was attached an indicator, which just cleared a metric scale upon the side of the bench; this device enabled the experimenter to ascertain the distance of the sheet of letters from the eye of the observer at any given setting of the carriage.

The sheets upon which the isolated letters were printed were 21 cm. wide and 36 cm. long; and the paper of all of the sheets was of the same quality and texture.[5] Each sheet contained twenty-eight letters, all of the same face and of the same case,—the complete alphabet, with two of its letters repeated. The letters were arranged in random sequence, in four lines; they were so spaced that each letter stood at a distance of 3.7 cm. from its nearest neighbors on the same and on adjacent lines. Fifty-two different sheets of letters were investigated, representing the following twenty-six faces of type, both lower case and upper case. All of our letters were of the size which is technically described as ten-point; the reader will find them illustrated in Tables I and II. (See inserts between pages 8 and 9.)

American Typewriter
Bold Antique
Bulfinch
Caslon Oldstyle No. 540
Century Oldstyle
Century Oldstyle, Bold
Century Expanded
Cheltenham Oldstyle

[5] This paper is technically described by the manufacturers as a white, coated book-paper, 25 x 30 — 80.

Cheltenham Bold
Cheltenham Bold, Condensed
Cheltenham Italic
Cheltenham Wide
Clearface
Clearface Bold
Clearface Italic
Clearface Bold Italic
Cushing No. 2
Cushing Oldstyle No. 2
Cushing Monotone
Della Robbia
DeVinne No. 2
DeVinne No. 2, Italic
Franklin Gothic
Jenson Oldstyle No. 2
News Gothic
Ronaldson Oldstyle No. 551

b. Method of Procedure

All of the readings were made in a semi-darkened room, in order that the (artificial) illumination upon the sheet of letters might be controlled and kept constant throughout. The experimental procedure was as follows: After the observer had become adapted to the illumination of the room, a sheet of letters was placed in position in the carriage and the series of readings began with the carriage at the farther end of the bench. The observer had been instructed to read the letters at a uniform tempo, substituting "blank" for the name of any letter which was not easily decipherable. This precaution seemed necessary to prevent the observer from giving an undue amount of attention to any one letter of the series at the expense of the other letters, i. e., to prevent him from puzzling longer over one member of the series than over any other member. After he had thus attempted to read through the complete list of letters, the carriage was moved to a point twenty centimeters nearer his eye than the initial setting; and he made a second attempt to read

the letters. In the first and alternate readings of each series he began at the upper left-hand corner of the sheet and proceeded from left to right along each line, taking the lines, in order, from the top downward. In the second and alternate readings, he began at the lower right-hand corner of the sheet and proceeded from right to left, and from below upwards. This procedure was continued, the carriage being advanced step by step, until every letter upon the sheet had been identified. The experimenter was provided with a duplicate sheet of letters, similar to the one which had been inserted in the carriage; and upon this duplicate sheet she recorded the misreadings, and the farthest distance at which each letter was read.

Each of the fifty-two sheets of letters was read twice by each of the six observers. Before being inserted in the carriage for its second reading, each sheet was cut along its longitudinal and its transverse diameters; and the four quarter-sheets were reassembled in such fashion that those letters which had formerly appeared upon the marginal regions of the original sheet now appeared upon central regions of the reconstructed sheet, and *vice versa*. A period of several days always elapsed between the first and the second reading of any sheet.

c. Observers

The observers were instructors or students in the department: Messrs. R. Acher, J. W. Baird, E. O. Finkenbinder, F. A. Lombard, H. B. Moyle, and C. W. St. John; they all possessed emmetropic or adequately corrected vision. Each observer gave a complete series of one hundred and four readings.

B. GROUPED LETTERS

In the second group of experiments the apparatus and the method remained unchanged, but here the letters were presented in groups instead of singly. In these later experiments only lower case letters were employed. Eight faces were elected from the twenty-six which had already been

used, and Scotch Roman was added,—the complete list of nine faces being as follows:

Bulfinch
Caslon Oldstyle No. 540
Century Oldstyle
Century Expanded
Cheltenham Wide
Cushing Oldstyle No. 2
Cushing Monotone
News Gothic
Scotch Roman

Each group of letters formed a nonsense combination; and the groups of each face were arranged in three lines upon sheets of the same size as had been employed in the former experiments. Sets of grouped letters were printed, in duplicate, upon coated book paper, of the good quality and upon an antique laid book paper of the same quality and weight as the paper of this page.

Our mode of grouping the letters aimed to introduce as many difficult and confusing combinations of letters as possible. We were guided in the combining of the letters into groups by data furnished by Mr. L. D. Evans, an expert proofreader, and by the confusions which had been recorded in our earlier experiments. The combinations of letters which are here appended illustrate a typical series of groups; they also illustrate the Scotch Roman face.

ksitugy cdzxpbj ftoceygqa wrvlindh
hknurfkxzqg munimm bhwvjyst oceo
wvxarlizxp ybhdonactilsf dnupqcetrlj

Only three observers, Messrs. Baird, Finkenbinder and St. John, took part in these experiments. Each observer gave two readings of each face,—an average of twenty-four readings of each letter of each face.

TABLE I. UPPER CASE. ISOLATED LETTERS

SHOWING THE AVERAGE DISTANCE, EXPRESSED IN CM., AT WHICH EACH LETTER OF EACH FACE WAS READ (TWELVE READINGS, SIX OBSERVERS). THE FIRST COLUMN IN EACH DIVISION OF THE TABLE SHOWS THE ACTUAL SIZE AND FORM OF THE LETTER WHICH WAS PRESENTED FOR IDENTIFICATION; AND THE NUMBER INDICATES THE AVERAGE DISTANCE, FROM THE EYE, AT WHICH THE LETTER WAS CORRECTLY IDENTIFIED

American Typewriter		Bulfinch		Caslon O. S.		Century O. S.		Century Expanded		Cheltenham O. S.		Cheltenham Wide	Clearface		Cushing O. S.		Cushing No. 2		Cushing Monotone		Della Robbia		De Vinne No. 2		Jenson O. S.		News Gothic		Ronaldson O. S.		*Average*
A	221.7	A	280	A	270	A	300	A	300	A	291.7		A	281.9	A	257.5	A	241.7	A	234.2	A	293.3	A	265	A	300	A	286.7	A	263.3	272.4
B	176.7	B	231.7	B	206.7	B	221.7	B	213.3	B	210		B	221.7	B	204.2	B	190.8	B	179.2	B	211.7	B	211.7	B	229.2	B	230.8	B	195	208.9
C	195	C	293.3	C	278.3	C	285	C	271.2	C	290		C	288.8	C	259.1	C	243.3	C	251.7	C	282.5	C	252.5	C	310	C	276.7	C	259.2	265.1
D	183.3	D	275	D	265	D	281.7	D	273.3	D	270		D	251.7	D	255.8	D	218.3	D	236.7	D	243.3	D	249.2	D	300	D	265	D	246.7	254.3
E	193.3	E	230.8	E	213.3	E	241.7	E	240.8	E	259.2		E	229.6	E	198.3	E	209.2	E	192.5	E	228.3	E	226.7	E	245.8	E	240	E	208.3	223.9
F	191.7	F	254.2	F	210.8	F	265	F	265.8	F	241.7		F	270.7	F	234.2	F	208.3	F	217.5	F	244.2	F	243.3	F	276.7	F	253.3	F	241.7	241.6
G	169.2	G	276.7	G	256.7	G	265	G	255	G	275		G	258.6	G	220	G	197.5	G	214.2	G	256.7	G	184.2	G	273.3	G	247.5	G	213.3	237.6
H	190	H	266.7	H	230	H	250	H	239.2	H	256.7		H	261.2	H	213.3	H	202.5	H	214.2	H	283.3	H	233.3	H	273.3	H	253.3	H	240	240.5
I	230	I	300	I	285	I	295	I	275	I	268.3		I	327.2	I	290	I	244.2	I	251.7	I	301.7	I	273.3	I	296.7	I	296.7	I	270	280.4
J	226.7	J	290	J	285	J	300	J	301.7	J	281.7		J	323	J	295	J	271.7	J	260	J	315	J	275.0	J	320	J	295	J	281.7	287.5
K	177.5	K	262.5	K	220.8	K	256.7	K	241.7	K	254.2		K	236	K	228.3	K	205.8	K	200	K	217.5	K	243.3	K	270	K	231.7	K	229.2	231.7
L	248.3	L	305	L	281.7	L	308.3	L	301.7	L	300		L	315.1	L	296.7	L	261.7	L	266.7	L	296.7	L	290	L	311.7	L	300	L	283.3	291.1
M	189.2	M	316.7	M	290	M	313.3	M	298.3	M	303.3		M	323	M	315	M	273.3	M	275	M	321.8	M	293.3	M	318.3	M	308.3	M	268.3	293.8
N	184.2	N	246.7	N	244.2	N	258.3	N	241.7	N	261.7		N	247	N	221.7	N	201.7	N	215	N	258.3	N	225	N	270	N	243.3	N	225	235.5
O	186.7	O	293.3	O	267.5	O	293.3	O	265	O	278.3		O	274.5	O	230.8	O	215.8	O	219.2	O	275	O	226.7	O	296.7	O	250	O	253.3	254.0
P	190	P	301.7	P	245	P	263.3	P	281.7	P	270.8		P	286	P	255	P	238.3	P	229.2	P	252.5	P	263.3	P	296.7	P	278.3	P	229.2	257.9
Q	214.2	Q	308.3	Q	270	Q	268.3	Q	275	Q	291.7		Q	285	Q	255.8	Q	220	Q	245	Q	246.7	Q	240.9	Q	295	Q	278.3	Q	231.7	261.7
R	186.7	R	227.5	R	200.8	R	210.7	R	235	R	255		R	216.9	R	198.3	R	196.7	R	180	R	228.3	R	193.3	R	234.2	R	240	R	205.8	214.0
S	168.3	S	236.7	S	197.5	S	225	S	209.2	S	215		S	211.2	S	210	S	182.5	S	183.3	S	203.3	S	200	S	223.3	S	216.7	S	203.3	205.7
T	220.8	T	276.7	T	280	T	305	T	280	T	271.2		T	273.9	T	280	T	219.2	T	237.5	T	295	T	251.7	T	308.3	T	280.8	T	251.7	268.9
U	200.8	U	268.3	U	247.5	U	256 7	U	276.7	U	266.7		U	269.1	U	233.3	U	220	U	232.5	U	275	U	240.9	U	270.8	U	273.3	U	237.5	251.3
V	205	V	275	V	255.8	V	281.7	V	278.3	V	288.3		V	277.6	V	246.7	V	237.5	V	236.7	V	291.7	V	248.3	V	310	V	264.2	V	256.7	263.5
W	165	W	310.7	W	291.7	W	306.7	W	316.7	W	306.7		W	318.2	W	331.7	W	288.3	W	285	W	343.3	W	315	W	306.7	W	316.7	W	301.7	300.2
X	192.5	X	260.8	X	237.5	X	257.5	X	250	X	263.3		X	247	X	240	X	212.5	X	222.5	X	252.5	X	236.7	X	256.7	X	240	X	228.3	239.8
Y	221.7	Y	268.3	Y	260	Y	271.7	Y	261.7	Y	249.2		Y	266	Y	250	Y	241.7	Y	233.3	Y	263.3	Y	225	Y	261.7	Y	258.3	Y	250.8	252.1
Z	187.5	Z	261.7	Z	228.3	Z	250	Z	237.5	Z	261.7		Z	240.7	Z	218.3	Z	204.2	Z	207.5	Z	256.7	Z	216.7	Z	270	Z	255.8	Z	210.7	233.8
Average	196.8		273.8		250.7		270.4		264.8		268.5			269.3		247.6		224.8		228.4		266.8		243.2		281.7		264.6		241.7	252.8

The Upper Case letters of Cheltenham Wide are identical with those of Cheltenham Old Style.

d. Results

A. ISOLATED LETTERS

The experimenter's record-sheet contained a statement of the distance at which each letter was read, together with a list of the confusions or misreadings, and an introspective description of the procedure which the observer had followed in deciphering the letters. The numerical data have been compiled and tabulated in various ways.

Tables I and II show the averages of the numerical results, arranged in order of faces. These two tables report the data for 'ordinary' faces only,—the italic, the bold and the condensed faces not being included here. The numbers which appear in these tables indicate the averages of the extreme distances at which the letters were read,—hence the larger the number appended to any letter, the greater the legibility of that letter. Thus, in the first column of Table I, "H 190, I 230" may be taken to signify that the upper case I of the American Typewriter face is considerably more legible than the upper case H of the same face.

Each vertical column of these two tables contains, therefore, a statement of our findings regarding the relative legibility of the various letters of a given face; and the number at the foot of the column indicates the average legibility of the twenty-six letters of that face. The numbers in each horizontal line of the tables indicate the relative legibility of each of the sixteen variants of each of the twenty-six letter forms.

Table III presents the grand averages of the sixteen faces; it also contains similar data for the bold and for the italic faces and for two extra-bold faces, Franklin Gothic and Bold Antique; while Table IV shows the grand average distance at which each letter of the alphabet was read, the data being here compiled from the readings of the complete set of sixteen faces.

The effect of certain definite modifications of a given letter-form is shown in Tables V and VI. These two tables are compiled from results which were obtained with Cheltenham Old-

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Each vertical column of these two tables contains, therefore, a statement of our findings regarding the relative legibility of the various letters of a given face; and the number at the foot of the column indicates the average legibility of the twenty-six letters of that face. The numbers in each horizontal line of the tables indicate the relative legibility of each of the sixteen variants of each of the twenty-six letter forms.

Table III presents the grand averages of the sixteen faces; it also contains similar data for the bold and for the italic faces and for two extra-bold faces, Franklin Gothic and Bold Antique; while Table IV shows the grand average distance at which each letter of the alphabet was read, the data being here compiled from the readings of the complete set of sixteen faces.

The effect of certain definite modifications of a given letter-form is shown in Tables V and VI. These two tables are compiled from results which were obtained with Cheltenham Old-

style presented in ordinary, in bold, in bold-condensed, (in wide,) and in italicized form.

Tables VII, VIII, IX, and X show the five variants of each letter which proved to be most legible, and the five which proved to be least legible.

B. GROUPED LETTERS

The results of our second series of experiments are presented in Tables XI and XII. Table XI shows the average distance at which each letter of each of the nine faces was read when presented in groups. The reader is warned against drawing any conclusion from this table regarding the relative legibility of the various letters of any given face, e.g., regarding the relative legibility of the Caslon m and the Caslon, or any other, k. In other words, the numbers which appear in the horizontal lines are comparable with one another; but the numbers which appear in the vertical columns are incomparable with one another. Table XII presents the same results as are contained in Table XI, but they are now arranged in order of magnitude in order to show the (descending) order of legibility of the several variants of each letter-form.

IV. DISCUSSION OF RESULTS

A. ISOLATED LETTERS

The problem with which we are here concerned may be given the following general formulation: Which of several geometrical figures is most clearly perceptible, and most readily distinguishable from other geometrical figures? But while the twenty-six letter-forms which constitute the alphabet may be regarded as a series of geometrical figures of different shapes and of different degrees of complexity of detail, and while any twenty-five of the different twenty-six different faces of type which were employed in the present investigation may be regarded as variants from the twenty-sixth or common letter-form, yet, as a matter of fact, such a simple mode of envisagement of our problem does not do justice to the complex conditions which are found to be

N IN EACH DIVISION OF THE TABLE SHOWS THE ACTUAL SIZE AND FORM OF THE
ICH THE LETTER WAS CORRECTLY IDENTIFIED

a Robbia		De Vinne No. 2		Jenson O. S.		News Gothic		Ronaldson O. S.		*Average*
167.5	**a**	174.2	a	183.3	a	190	a	169.2		177.0
223.3	**b**	195.8	b	220	b	245	b	219.2		217.8
181.7	**c**	182.5	c	197.5	c	221.7	c	190.8		193.8
276.7	**d**	253.3	d	246.7	d	256.7	d	245		254.3
175	**e**	170	e	191.7	e	191.7	e	165		173.5
260	**f**	205	f	225	f	263.3	f	235		233.0
218.3	**g**	196.7	g	202.5	g	258.3	g	198.3		220.8
236.7	**h**	205	h	220	h	235.8	h	232.5		222.7
219.2	**i**	214.2	i	231.7	i	249.2	i	204.2		224.1
210.8	**j**	236.7	j	210	j	280.8	j	247.5		239.4
206.7	k	215	k	230	k	233.3	k	224.2		216.9
250	**l**	190.8	l	251.7	l	226.7	l	243.3		236.3
295	**m**	315	m	291.7	m	326.7	m	300		296.8
203.3	**n**	197.5	n	206.7	n	220	n	190		195.7
193.3	**o**	170.8	o	188.3	o	207.5	o	180		190.1
239.3	**p**	225	p	255	p	248.3	p	217.5		236.1
238.3	**q**	212.5	q	220.8	q	257.5	q	217.5		226.4
190	**r**	198.3	r	196.7	r	237.5	r	181.7		203.6
138.3	**s**	154.2	s	150	s	177.5	s	141.8		152.6
191.7	**t**	191.7	t	188.3	t	223.3	t	202.5		199.6
195	**u**	194.2	u	180	u	215	u	185.8		193.1
205.8	**v**	199.2	v	219.2	v	235.8	v	219.2		213.1
280	**w**	265	w	270	w	305	w	263.3		261.6
171.7	**x**	185	x	192.5	x	196.7	x	170		181.7
226.7	**y**	208.3	y	241.7	y	246.7	y	210		224.6
175	**z**	170	z	171.7	z	199.2	z	185		171.6
214.2		204.8		214.7		236.4		209.2		213.7

TABLE II. LOWER CASE

SHOWING THE AVERAGE DISTANCE, EXPRESSED IN CM., AT WHICH EACH LETTER OF EACH FACE WAS READ (TWELVE READINGS, SIX OBSERVERS). THE FIRST COLUMN IN EACH DIVISION OF THE TABLE SHOWS THE ACTUAL SIZE AND FORM OF THE LETTER WHICH WAS PRESENTED FOR IDENTIFICATION; AND THE NUMBER INDICATES THE AVERAGE DISTANCE, FROM THE EYE, AT WHICH THE LETTER WAS CORRECTLY IDENTIFIED

American Typewriter		Bulfinch		Caslon O. S.		Century O. S.		Century Expanded		Cheltenham O. S.		Cheltenham Wide		Clearface		Cushing O. S.		Cushing No. 2		Cushing Monotone		Della Robbia		De Vinne No. 2		Jenson O. S.		News Gothic		Ronaldson O. S.		*Average*
a	184.2	a	185	a	170.8	a	197.5	a	196.7	a	155	a	190.8	a	182.1	a	173.3	a	155.8	a	155.8	a	167.5	a	174.2	a	183.3	a	190	a	169.2	177.0
b	208.3	b	233.3	b	190	b	245	b	233.3	b	221.7	b	245	b	223	b	206.7	b	171.7	b	203.3	b	223.3	b	195.8	b	220	b	245	b	219.2	217.8
c	168.3	c	207.5	c	185	c	230	c		c	180.8	c	200.8	c	235.9	c	179.2	c	174.2	c	171.7	c	181.7	c	182.5	c	197.5	c	221.7	c	190.8	193.8
d	230	d	258.3	d	253.3	d		d	273.3	d	261.7	d	276.7	d	283.4	d	260	d	205.8	d	233.3	d	276.7	d	253.3	d	246.7	d	256.7	d	245	254.3
e	162.5	e	181.7	e	165.8	e	199.1	e	187.5	e	169.2	e	185.8	e	179.8	e	164.2	e	140	e	146.7	e	175	e	170	e	191.7	e	191.7	e	165	173.5
f	241.7	f	261.7	f	225	f	256.7	f	256.7	f	235	f	241.7	f	241.7	f	232.5	f	184.2	f	178.3	f	260	f	205	f	225	f	263.3	f	235	233.0
g	203.3	g	251.7	g	182.5	g	245	g	241.7	g	195.8	g	216.7	g	250	g	231.7	g	225.8	g	215	g	218.3	g	196.7	g	202.5	g	258.3	g	198.3	220.8
h	207.5	h	241.7	h	210.8	h	235	h	238.3	h	211.7	h	238.3	h	247	h	211.7	h	190.8	h	200	h	236.7	h	205	h	220	h	235.8	h	232.5	222.7
i	206.7	i	243.3	i	209.2	i	245	i	215.8	i	235	i	251.7	i	213	i	231.7	i	200	i	215	i	219.2	i	214.2	i	231.7	i	249.2	i	204.2	224.1
j	256.7	j	228.3	j	235	j	240	j	283.3	j	234.2	j	248.3	j	264.4	j	227.5	j	218.3	j	208.3	j	210.8	j	236.7	j	210	j	280.8	j	247.5	239.4
k	188.3	k	236.7	k	197.5	k	240	k	235	k	211.7	k	224.2	k	223.2	k	221.7	k	183.3	k	200	k	206.7	k	215	k	230	k	233.3	k	224.2	216.9
l	230	l	256.7	l	219.2	l	245	l	252.5	l	240	l	254.2	l	280.2	l	232.5	l	208.3	l	199.2	l	250	l	190.8	l	251.7	l	226.7	l	243.3	236.3
m	195	m	336.7	m	291.7	m	310	m	286.7	m	295	m	315	m	325.1	m	315	m	273.3	m	276.7	m	295	m	315	m	291.7	m	326.7	m	300	296.8
n	195.8	n	213.3	n	190	n	213.3	n	199.2	n	181.7	n	208.3	n	213.7	n	172.5	n	162.5	n	163.3	n	203.3	n	197.5	n	206.7	n	220	n	190	195.7
o	188.3	o	220	o	180.8	o	211.7	o	213.3	o	181.7	o	189.2	o	199.5	o	172.5	o	170	o	175	o	193.3	o	170.8	o	188.3	o	207.5	o	180	190.1
p	238.3	p	271.7	p	220.8	p	240	p	240	p	223.3	p	247.5	p	259.7	p	245	p	205	p	201.7	p	239.3	p	225	p	255	p	248.3	p	217.5	236.1
q	233.3	q	240	q	221.7	q	233.3	q	233.3	q	221.7	q	219.2	q	234.4	q	235	q	196.7	q	206.7	q	238.3	q	212.5	q	220.8	q	257.5	q	217.5	226.4
r	210.8	r	216.7	r	203.3	r	216.7	r	225	r	187.5	r	214.2	r	215.4	r	205	r	175.8	r	183.3	r	190	r	198.3	r	196.7	r	237.5	r	181.7	203.6
s	149.2	s	167.5	s	145	s	167.5	s	165	s	138.3	s	160	s	150.4	s	145.8	s	145.8	s	145.5	s	138.3	s	154.2	s	150	s	177.5	s	141.8	152.6
t	198.3	t	230.8	t	180.8	t	206.7	t	221.7	t	183.3	t	190	t	228	t	208.3	t	169.2	t	179.2	t	191.7	t	191.7	t	188.3	t	223.3	t	202.5	199.6
u	198.3	u	225	u	185	u	212.5	u	198.3	u	177.5	u	197.5	u	207.4	u	175.8	u	176.7	u	165	u	195	u	194.2	u	180	u	215	u	185.8	193.1
v	195	v	240	v	180.8	v	230	v	217.5	v	205	v	223.3	v	225.4	v	225.8	v	183.3	v	205	v	205.8	v	199.2	v	219.2	v	235.8	v	219.2	213.1
w	183.3	w	271.7	w	243.3	w	266.7	w	268.3	w	263.3	w	293.3	w	296	w	281.7	w	201	w	233.3	w	280	w	265	w	270	w	305	w	263.3	261.6
x	180.8	x	211.7	x	171.7	x	200	x	195	x	169.2	x	184.2	x	178.1	x	187.5	x	157.5	x	155	x	171.7	x	185	x	192.5	x	196.7	x	170	181.7
y	230	y	245	y	221.7	y	230.8	y	218.3	y	222.5	y	236.7	y	237.5	y	227.5	y	194.2	y	195.8	y	226.7	y	208.3	y	241.7	y	246.7	y	210	224.6
z	159	z	196.7	z	162.5	z	182.5	z	171.7	z	164.2	z	179.2	z	171.4	z	157.5	z	156.7	z	143.3	z	175	z	170	z	171.7	z	199.2	z	185	171.6
Average	201.7		233.6		201.7		228.0		226.7		206.4		224.3		229.5		212.6		185.6		190.6		214.2		204.8		214.7		236 4		209.2	213.7

TABLE III. ISOLATED LETTERS

A Comparison of the Average Legibility of Various Faces. Order of Legibility

UPPER CASE		Lower Case	
The Sixteen Roman Faces			
JENSON	281.7	News Gothic	236.4
BULFINCH	273.8	Bulfinch	233.6
CHELT. W.	268.5	Clearface	229.5
CENTURY O. S.	270.4	Century O. S.	228.0
CLEARFACE	269.3	Century Exp.	226.7
CHELT. O. S.	268.5	Chelt. W.	224.3
DELLA ROBBIA	266.8	Jenson	214.7
NEWS GOTHIC	264.6	Della Robbia	214.2
CENTURY EXP.	264.8	**Cushing O. S.**	212.6
CASLON O. S.	250.7	Ronaldson	209.2
CUSHING O. S.	247.6	Chelt. O. S.	206.4
DE VINNE NO. 2	243.2	**De Vinne No. 2**	204.8
RONALDSON	241.7	American Typewr.	201.7
CUSHING MON.	228.4	Caslon O. S.	201.7
CUSHING NO. 2	224.8	Cushing Mon.	190.6
AMERICAN TYPEWR.	196.8	Cushing No. 2	185.6
Average	252.8	*Average*	213.7
Bold Faces			
CENT. O. S. BOLD	296.0	**Cent. O. S. Bold**	255.1
CHELT. O. S. BOLD	286.2	**Chelt. O. S. Bold**	233.4
CLEARFACE BOLD	273.7	**Clearface Bold**	230.5
Average (Bold)	285.3	*Average* (Bold)	239.7
Italic Faces			
CLEAR. ITALIC	274.3	*Clear. Italic*	231.2
CHELT. ITALIC	259.6	*Chelt. Italic*	203.8
DE VINNE ITALIC	235.5	***De Vinne Italic***	201.9
Average (Italic)	256.5	*Average* (Italic)	212.3
Average (of same faces, Roman)	260.3	*Average* (of same faces, Roman)	213.6
Bold Italic Face			
CLEAR. B. ITALIC	265.4	*Clearface B. Italic*	213.2
Extra Bold Faces			
BOLD ANT.	307.4	**Bold Antique**	260.5
FRANK. GOTHIC	284.8	**Franklin Gothic**	245.2

TABLE III. ISOLATED LETTERS

A Comparison of the Average Legibility of Various Faces. Order of Legibility

UPPER CASE		Lower Case	
The Sixteen Roman Faces			
JENSON	281.7	News Gothic	236.4
BULFINCH	273.8	Bulfinch	233.6
CHELT. W.	268.5	Clearface	229.5
CENTURY O. S.	270.4	Century O. S.	228.0
CLEARFACE	269.3	Century Exp.	226.7
CHELT. O. S.	268.5	Chelt. W.	224.3
DELLA ROBBIA	266.8	Jenson	214.7
NEWS GOTHIC	264.6	Della Robbia	214.2
CENTURY EXP.	264.8	**Cushing O. S.**	212.6
CASLON O. S.	250.7	Ronaldson	209.2
CUSHING O. S.	247.6	Chelt. O. S.	206.4
DE VINNE NO. 2	243.2	**De Vinne No. 2**	204.8
RONALDSON	241.7	American Typewr.	201.7
CUSHING MON.	228.4	Caslon O. S.	201.7
CUSHING NO. 2	224.8	Cushing Mon.	190.6
AMERICAN TYPEWR.	196.8	Cushing No. 2	185.6
Average	252.8	*Average*	213.7
Bold Faces			
CENT. O. S. BOLD	296.0	**Cent. O. S. Bold**	255.1
CHELT. O. S. BOLD	286.2	**Chelt. O. S. Bold**	233.4
CLEARFACE BOLD	273.7	**Clearface Bold**	230.5
Average (Bold)	285.3	*Average* (Bold)	239.7
Italic Faces			
CLEAR. ITALIC	274.3	*Clear. Italic*	231.2
CHELT. ITALIC	259.6	*Chelt. Italic*	203.8
DE VINNE ITALIC	235.5	***De Vinne Italic***	201.9
Average (Italic)	256.5	*Average* (Italic)	212.3
Average (of same faces, Roman)	260.3	*Average* (of same faces, Roman)	213.6
Bold Italic Face			
CLEAR. B. ITALIC	265.4	*Clearface B. Italic*	213.2
Extra Bold Faces			
BOLD ANT.	307.4	**Bold Antique**	260.5
FRANK. GOTHIC	284.8	**Franklin Gothic**	245.2

TABLE IV. ISOLATED LETTERS

THE RELATIVE LEGIBILITY OF THE LETTERS OF THE ALPHABET. (AVERAGE OF SIXTEEN FACES; 192 READINGS OF EACH LETTER)

UPPER CASE		Lower Case	
W	300.2	m	296.8
M	293.8	w	261.6
L	291.1	d	254.3
J	287.5	j	239.4
I	280.4	l	236.3
A	272.4	p	236.1
T	268.9	f	233.0
C	265.1	q	226.4
V	263.5	y	224.6
Q	261.7	i	224.1
P	257.9	h	222.7
D	254.3	g	220.6
O	254.0	b	217.8
Y	252.1	k	216.9
U	251.3	v	213.1
F	241.6	r	203.6
H	240.5	t	199.6
X	239.8	n	195.7
G	237.6	c	193.8
N	235.5	u	193.1
Z	233.8	o	190.1
K	231.7	x	181.7
E	223.9	a	177.0
R	214.0	e	173.5
B	208.9	z	171.6
S	205.7	s	152.6
Average	252.8	*Average*	213.8

TABLE V. UPPER CASE

THE EFFECT OF VARIOUS MODIFICATIONS OF A GIVEN FACE

Cheltenham

Ordinary	Bold	Bold Condensed	Wide	Italic
A 291.7	**A** 303.3	**A** 190.0	*The Upper Case letters of Cheltenham Wide are identical with those of Cheltenham Old Style (First Column of this Table).*	*A* 273.3
B 210.0	**B** 236.7	**B** 204.2		*B* 220.0
C 290.0	**C** 295.0	**C** 253.3		*C* 283.3
D 270.0	**D** 284.2	**D** 260.0		*D* 261.7
E 259.2	**E** 273.3	**E** 225.8		*E* 237.5
F 241.7	**F** 281.7	**F** 239.2		*F* 235.0
G 275.0	**G** 280.0	**G** 232.5		*G* 240.0
H 256.7	**H** 295.0	**H** 213.3		*H* 263.3
I 268.3	**I** 306.7	**I** 273.3		*I* 270 0
J 281.7	**J** 295.0	**J** 290.0		*J* 276.7
K 254.2	**K** 277.5	**K** 234.2		*K* 240.8
L 300.0	**L** 311.7	**L** 280.0		*L* 288.3
M 303.3	**M** 321.7	**M** 295.0		*M* 301.7
N 261.7	**N** 270.0	**N** 216.7		*N* 256.7
O 278.3	**O** 295.0	**O** 243.3		*O* 280.0
P 270.8	**P** 293.3	**P** 240.8		*P* 286.7
Q 291.7	**Q** 300.0	**Q** 258.3		*Q* 286.7
R 255.0	**R** 253.3	**R** 205.0		*R* 244.2
S 215.0	**S** 228.2	**S** 187.5		*S* 206.7
T 271.2	**T** 306.7	**T** 271.7		*T* 258.3
U 266.7	**U** 298.3	**U** 240.0		*U* 263.3
V 288.3	**V** 305.0	**V** 254.2		*V* 240.8
W 306.7	**W** 323.3	**W** 300.0		*W* 278.3
X 263.3	**X** 270.0	**X** 255.0		*X* 242.5
Y 249.2	**Y** 273.3	**Y** 256.7		*Y* 245.0
Z 261.7	**Z** 263.3	**Z** 235.0		*Z* 268.3
Average 268.5	286.2	248.2		259.6

TABLE VI. LOWER CASE

THE EFFECT OF VARIOUS MODIFICATIONS OF A GIVEN FACE

Cheltenham

Ordinary		Bold		Bold Condensed		Wide		Italic	
a	155.0	**a**	195.8	**a**	167.5	a	190.8	*a*	159.2
b	221.7	**b**	221.7	**b**	209.2	b	245.0	*b*	195.0
c	180.8	**c**	198.3	**c**	185.8	c	200.8	*c*	192.5
d	261.7	**d**	285.0	**d**	275.0	d	276.7	*d*	263.3
e	169.2	**e**	185.8	**e**	170.8	e	185.8	*e*	165.0
f	235.0	**f**	244.2	**f**	214.2	f	241.7	*f*	261.7
g	195.8	**g**	222.5	**g**	202.5	g	216.7	*g*	216.7
h	211.7	**h**	251.7	**h**	238.3	h	238.3	*h*	241.7
i	235.0	**i**	226.7	**i**	206.7	i	251.7	*i*	251.7
j	234.2	**j**	280.0	**j**	246.7	j	248.3	*j*	222.5
k	211.7	**k**	225.8	**k**	244.2	k	224.2	*k*	217.5
l	240.0	**l**	270.0	**l**	231.7	l	254.2	*l*	230.0
m	295.0	**m**	301.7	**m**	273.3	m	315.0	*m*	273.3
n	181.7	**n**	217.5	**n**	175.8	n	208.3	*n*	198.3
o	181.7	**o**	192.5	**o**	160.0	o	189.2	*o*	169.2
p	223.3	**p**	255.0	**p**	225.8	p	247.5	*p*	223.3
q	221.7	**q**	255.0	**q**	205.8	q	219.2	*q*	196.7
r	187.5	**r**	223.3	**r**	199.2	r	214.2	*r*	205.8
s	138.3	**s**	140.8	**s**	135.8	s	160.0	*s*	131.7
t	183.3	**t**	222.5	**t**	208.3	t	190.0	*t*	192.5
u	177.5	**u**	217.5	**u**	170.8	u	197.5	*u*	179.2
v	205.0	**v**	263.3	**v**	208.3	v	223.3	*v*	158.3
w	263.3	**w**	300.0	**w**	261.7	w	293.3	*w*	245.0
x	169.2	**x**	190.8	**x**	185.0	x	184.2	*x*	174.2
y	222.5	**y**	245.0	**y**	224.2	y	236.7	*y*	174.2
z	164.2	**z**	175.8	**z**	154.2	z	179.2	*z*	160.0
Average	206.4		233.4		205.9		224.3		203.8

TABLE VII. THE FIVE MOST LEGIBLE ALPHABETS. UPPER CASE

THE FIRST COLUMN CONTAINS THE "IDEAL ALPHABET", OR THE FACES WHICH PROVED TO BE MOST LEGIBLE; THE SECOND COLUMN GIVES THE FACES WHICH RANKED SECOND IN ORDER OF LEGIBILITY, ETC.

A	Century Exp.	300	A	Century O. S.	300	A	Jenson	300	A	Della Robbia	293.3	A	Chelt. O. S.	291.7
B	Bulfinch	231.7	B	News Gothic	230.8	B	Jenson	229.2	B	Clearface	221.7	B	Century O. S.	221.7
C	Jenson	310	C	Bulfinch	293.3	C	Chelt. O. S.	290	C	Clearface	288.8	C	Century O. S.	285
D	Jenson	300	D	Century O. S.	281.7	D	Bulfinch	275	D	Century Exp.	273.3	D	Chelt. O. S.	270
E	Chelt. O. S.	259.2	E	Jenson	245.8	E	Century O. S.	241.7	E	Century Exp.	240.8	E	News Gothic	240
F	Jenson	276.7	F	Clearface	270.7	F	Century Exp.	265.8	F	Century O. S.	265	F	Bulfinch	254.2
G	Bulfinch	276.7	G	Chelt. O. S.	275	G	Jenson	273.3	G	Century O. S.	265	G	Clearface	258.6
H	Della Robbia	283.3	H	Jenson	273.3	H	Bulfinch	266.7	H	Clearface	261.2	H	Chelt. O. S.	256.7
I	Clearface	327.2	I	Della Robbia	301.7	I	Bulfinch	300	I	News Gothic	296.7	I	Jenson	296.7
J	Clearface	323	J	Jenson	320	J	Della Robbia	315	J	Century Exp.	301.7	J	Century O. S.	300
K	Jenson	270	K	Bulfinch	262.5	K	Century O. S.	256.7	K	Chelt. O. S.	254.2	K	DeVinne No. 2	243.3
L	Clearface	315.1	L	Jenson	311.7	L	Century O. S.	308.3	L	Bulfinch	305	L	Century Exp.	301.7
M	Clearface	323	M	Della Robbia	321.8	M	Jenson	318.3	M	Bulfinch	316.7	M	Cushing O. S.	315
N	Jenson	270	N	Chelt. O. S.	261.7	N	Della Robbia	258.3	N	Century O. S.	258.3	N	Clearface	247
O	Jenson	296.7	O	Century O. S.	293.3	O	Bulfinch	293.3	O	Chelt. O. S.	278.3	O	Della Robbia	275
P	Bulfinch	301.7	P	Jenson	296.7	P	Clearface	286	P	Century Exp.	281.7	P	News Gothic	278.3
Q	Bulfinch	308.3	Q	Jenson	295	Q	Chelt. O. S.	291.7	Q	Clearface	285	Q	News Gothic	278.3
R	Chelt. O. S.	255	R	News Gothic	240	R	Century Exp.	235	R	Jenson	234.2	R	Della Robbia	228.3
S	Bulfinch	236.7	S	Century O. S.	225	S	Jenson	223.3	S	News Gothic	216.7	S	Chelt. O. S.	215
T	Jenson	308.3	T	Century O. S.	305	T	Della Robbia	295	T	News Gothic	280.8	T	Cushing O. S.	280
U	Century Exp.	276.7	U	Della Robbia	275	U	News Gothic	273.3	U	Jenson	270.8	U	Clearface	269.1
V	Jenson	310	V	Della Robbia	291.7	V	Chelt. O. S.	288.3	V	Century O. S.	281.7	V	Century Exp.	278.3
W	Della Robbia	343.3	W	Century O. S.	331.7	W	Clearface	318.2	W	Century Exp.	316.7	W	News Gothic	316.7
X	Chelt. O. S.	263.3	X	Bulfinch	260.8	X	Century O. S.	257.5	X	Jenson	256.7	X	Della Robbia	252.5
Y	Century O. S.	271.7	Y	Bulfinch	268.3	Y	Clearface	266	Y	Della Robbia	263.3	Y	Jenson	261.7
Z	Jenson	270	Z	Chelt. O. S.	261.7	Z	Bulfinch	216.7	Z	Della Robbia	256.7	Z	News Gothic	255.8

TABLE VIII. THE FIVE MOST LEGIBLE ALPHABETS. LOWER CASE

THE FIRST COLUMN CONTAINS THE IDEAL ALPHABET; OR THE FACES WHICH PROVED TO BE MOST LEGIBLE; THE SECOND COLUMN GIVES THE FACES WHICH RANKED SECOND IN ORDER OF LEGIBILITY, ETC.

a	Century O. S.	197.5	a	Century Exp.	196.7	a	Chelt. W.	190.8	a	News Gothic	190	a	Bulfinch	185
b	Century O. S.	245	b	Chelt. W.	245	b	News Gothic	245	b	Della Robbia	223.3	b	Clearface	223
c	Clearface	235.9	c	Century O. S.	230	c	News Gothic	221.7	c	Bulfinch	207.5	c	Chelt. W.	200.8
d	Clearface	283.4	d	Chelt. W.	276.7	d	Della Robbia	276.7	d	Century Exp.	273.3	d	Cushing O. S.	260
e	Century O. S.	197.5	e	Jenson O. S.	191.7	e	News Gothic	191.7	e	Century Exp.	187.5	e	Chelt. W.	185.8
f	News Gothic	263.3	f	Bulfinch	261.7	f	Della Robbia	260	f	Century Exp.	256.7	f	Century O. S.	256.7
g	News Gothic	258.3	g	Bulfinch	251.7	g	Clearface	250	g	Century O. S.	245	g	Century Exp.	241.7
h	Clearface	247	h	Bulfinch	241.7	h	Century Exp.	238.3	h	Chelt. W.	238.3	h	Della Robbia	236.7
i	Chelt. W.	251.7	i	News Gothic	249.2	i	Century O. S.	245	i	Bulfinch	243.3	i	Chelt. O. S.	235
j	Century Exp.	283.3	j	News Gothic	280.8	j	Clearface	264.4	j	Am. Typewr.	256.7	j	Chelt. W.	248.3
k	Bulfinch	236.7	k	Century Exp.	235	k	Jenson O. S.	233.3	k	News Gothic	233.3	k	Chelt. W.	224.3
l	Clearface	280.2	l	Bulfinch	258.7	l	Chelt. W.	254.2	l	Century Exp.	252.5	l	Jenson O. S.	251.7
m	Bulfinch	333.3	m	News Gothic	326.7	m	Clearface	325.1	m	Chelt. W.	315	m	De Vinne No. 2	315
n	News Gothic	220	n	Bulfinch	213.3	n	Century O. S.	213.3	n	Clearface	213.7	n	Chelt. W.	208.3
o	Bulfinch	218.3	o	Century Exp.	213.3	o	Century O. S.	211.7	o	News Gothic	207.5	o	Clearface	199.5
p	Bulfinch	271.2	p	Clearface	259.7	p	Jenson O. S.	255	p	News Gothic	248.3	p	Chelt. W.	247.5
q	News Gothic	257.5	q	Century Exp.	250	q	Bulfinch	250	q	Della Robbia	238.3	q	Cushing O. S.	235
r	News Gothic	237.5	r	Century Exp.	226.7	r	Bulfinch	216.7	r	Century O. S.	216.7	r	Clearface	215.4
s	News Gothic	177.5	s	Bulfinch	167.5	s	Century O. S.	167.5	s	Century Exp.	163	s	Chelt. W.	160
t	Bulfinch	230.8	t	Clearface	228	t	News Gothic	223.3	t	Century Exp.	221.7	t	Cushing O. S.	208.3
u	Bulfinch	225	u	News Gothic	215	u	Century O. S.	212.5	u	Clearface	207.4	u	Century Exp.	198.3
v	Bulfinch	240	v	News Gothic	235.8	v	Century O. S.	230	v	Cushing O. S.	225.8	v	Clearface	225.4
w	News Gothic	305	w	Clearface	296	w	Chelt. W.	293.3	w	Cushing O. S.	281.7	w	Della Robbia	280
x	Bulfinch	211.7	x	Century O. S.	200	x	Century Exp.	195	x	News Gothic	193.3	x	Jenson O. S.	192.5
y	News Gothic	246.7	y	Bulfinch	245	y	Jenson O. S.	241.7	y	Clearface	237.5	y	Chelt. W.	236.7
z	News Gothic	197.5	z	Bulfinch	196.7	z	Century O. S.	182.5	z	Chelt. W.	179.2	z	Jenson O. S.	171.7

TABLE IX. THE FIVE LEAST LEGIBLE ALPHABETS. UPPER CASE

THE FIRST COLUMN SHOWS THE LEAST LEGIBLE ALPHABET WHICH COULD BE MADE UP FROM OUR SIXTEEN FACES; THE SECOND COLUMN SHOWS THE FACES WHICH RANK SECOND IN ORDER OF ILLEGIBILITY, ETC.

A	Am. Typewr.	221.7	A	Cushing Mon.	234.2	A	Cushing No. 2	241.7	A	Cushing O. S.	257.5	A	Ronaldson	263.3
B	Am. Typewr.	176.7	B	Cushing Mon.	179.2	B	Ronaldson	196.7	B	Cushing O. S.	204.2	B	Caslon O. S.	206.7
C	Am. Typewr.	195	C	Cushing No. 2	243.3	C	Cushing Mon.	251.7	C	Cushing O. S.	259.2	C	Ronaldson	259.2
D	Am. Typewr.	183.3	D	Cushing No. 2	218.3	D	Cushing Mon.	236.7	D	Della Robbia	243.3	D	Ronaldson	246.7
E	Cushing Mon.	192.5	E	Am. Typewr.	193.3	E	Cushing O. S.	198.3	E	Ronaldson	208.3	E	Cushing No. 2	209.2
F	Am. Typewr.	191.7	F	Cushing No. 2	208.3	F	Caslon O. S.	210.7	F	Cushing Mon.	217.5	F	Cushing O. S.	234.2
G	Am. Typewr.	169.2	G	De Vinne No. 2	184.2	G	Cushing No. 2	197.5	G	Ronaldson	213.3	G	Cushing Mon.	214.2
H	Am. Typewr.	190	H	Cushing No. 2	202.5	H	Cushing O. S.	213.3	H	Cushing Mon.	214.2	H	De Vinne No. 2	233.3
I	Am. Typewr.	230	I	Cushing No. 2	244.2	I	Cushing Mon.	256.7	I	Chelt. O. S.	268.3	I	Ronaldson	270
J	Am. Typewr.	226.7	J	Cushing Mon.	260	J	De Vinne No. 2	266.7	J	Cushing No. 2	271.2	J	Ronaldson	281.7
K	Am. Typewr.	177.5	K	Cushing Mon.	200	K	Della Robbia	217.5	K	Caslon O. S.	220.8	K	Cushing O. S.	228.3
L	Am. Typewr.	248.3	L	Cushing No. 2	261.7	L	Cushing Mon.	266.7	L	Caslon O. S.	281.7	L	Ronaldson	283.3
M	Am. Typewr.	189.2	M	Ronaldson	268.3	M	Cushing No. 2	273.3	M	Cushing Mon.	275	M	De Vinne No. 2	290
N	Am. Typewr.	184.2	N	Cushing No. 2	201.7	N	Cushing Mon.	215	N	Cushing O. S.	220	N	Ronaldson	225
O	Am. Typewr.	186.7	O	Cushing No. 2	215	O	Cushing Mon.	219.2	O	De Vinne No. 2	226.7	O	Cushing O. S.	230.8
P	Am. Typewr.	190	P	Ronaldson	229.2	P	Cushing Mon.	236.7	P	Cushing No. 2	238.3	P	Caslon O. S.	245
Q	Am. Typewr.	217.5	Q	Cushing No. 2	220	Q	De Vinne No. 2	224.2	Q	Ronaldson	231.7	Q	Cushing Mon.	245
R	Cushing Mon.	180	R	Am. Typewr.	186.7	R	De Vinne No. 2	193.3	R	Cushing No. 2	196.7	R	Cushing O. S.	198.3
S	Am. Typewr.	168.3	S	Cushing No. 2	182.5	S	Cushing Mon.	183.3	S	Caslon O. S.	197.5	S	De Vinne No. 2	200
T	Cushing No. 2	219.2	T	Am. Typewr.	220.8	T	Cushing Mon.	237.5	T	De Vinne No. 2	251.7	T	Ronaldson	251.7
U	Am. Typewr.	200.8	U	Cushing No. 2	220	U	Cushing Mon.	232.5	U	Cushing O. S.	233.3	U	Ronaldson	237.5
V	Am. Typewr.	205	V	Cushing Mon.	236.7	V	Cushing No. 2	237.5	V	Cushing O. S.	246.7	V	De Vinne No. 2	248.3
W	Am. Typewr.	165	W	Cushing Mon.	285	W	Cushing No. 2	288.3	W	Caslon O. S.	291.7	W	Ronaldson	301.7
X	Am. Typewr.	192.5	X	Cushing No. 2	212.5	X	Cushing Mon.	222.5	X	Ronaldson	228.3	X	De Vinne No. 2	236.7
Y	Am. Typewr.	221.7	Y	De Vinne No. 2	225	Y	Cushing Mon.	233.3	Y	Cushing No. 2	241.7	Y	Chelt. O. S.	249.2
Z	Am. Typewr.	187.5	Z	Cushing No. 2	204.2	Z	Cushing Mon.	207.5	Z	Ronaldson	210.7	Z	De Vinne No. 2	216.7

TABLE X. THE FIVE LEAST LEGIBLE ALPHABETS. LOWER CASE

THE FIRST COLUMN SHOWS THE LEAST LEGIBLE ALPHABET WHICH COULD BE MADE UP FROM OUR SIXTEEN FACES; THE SECOND COLUMN SHOWS THE FACES WHICH RANK SECOND IN ORDER OF ILLEGIBILITY, ETC.

a	Chelt. O. S.	155	a	Cushing No. 2	155.8	a	Cushing Mon.	155.8	a	Della Robbia	167.5	a	Ronaldson O.S.	169.2
b	Cushing No. 2	171.7	b	Caslon O. S.	190	b	De Vinne No. 2	195.8	b	Cushing Mon.	203.3	b	Cushing O. S.	206.7
c	Am. Typewr.	168.3	c	Cushing Mon.	171.7	c	Cushing No. 2	174.2	c	Cushing O. S.	179.2	c	Della Robbia	181.7
d	Cushing No. 2	205.8	d	Am. Typewr.	230	d	Cushing Mon.	233.3	d	Ronaldson O.S.	245	d	Jenson O. S.	246.7
e	Cushing No. 2	140	e	Cushing Mon.	146.7	e	Am. Typewr.	162.5	e	Cushing O. S.	164.2	e	Ronaldson O.S.	165
f	Cushing Mon.	178.3	f	Cushing No. 2	184.2	f	De Vinne No. 2	205	f	Jenson O. S.	225	f	Caslon O. S.	225
g	Caslon O. S.	182.5	g	De Vinne No. 2	191.7	g	Chelt. O. S.	195.8	g	Ronaldson O.S.	198.3	g	Jenson O. S.	202.5
h	Cushing No. 2	190.8	h	Cushing Mon.	200	h	De Vinne No. 2	205	h	Am. Typewr.	207.5	h	Caslon O. S.	210.7
i	Cushing No. 2	200	i	Ronaldson O.S.	204.2	i	Am. Typewr.	206.7	i	Caslon O. S.	209.2	i	De Vinne No. 2	214.2
j	Cushing Mon.	298.3	j	Della Robbia	210.7	j	Jenson O. S.	210	j	Cushing No. 2	218.3	j	Cushing O. S.	227.5
k	Cushing No. 2	183.3	k	Am. Typewr.	188.3	k	Caslon O. S.	197.5	k	Cushing Mon.	200	k	Della Robbia	206.7
l	Cushing Mon.	197.5	l	De Vinne No. 2	190.8	l	Cushing No. 2	208.3	l	Caslon O. S.	219.2	l	News Gothic	221.7
m	Am. Typewr.	195	m	Cushing No. 2	273.3	m	Cushing Mon.	276.7	m	Century Exp.	286.7	m	Caslon O. S.	291.7
n	Cushing No. 2	162.5	n	Cushing Mon.	164.3	n	Cushing O. S.	172.5	n	Chelt. O. S.	181.7	n	Caslon O. S.	190
o	Cushing No. 2	170	o	De Vinne No. 2	170.8	o	Cushing O. S.	172.5	o	Cushing Mon.	175	o	Ronaldson O.S.	180
p	Cushing Mon.	200.8	p	Cushing No. 2	205	p	Ronaldson O.S.	217.5	p	Caslon O. S.	220.8	p	Chelt. O. S.	223.3
q	Cushing No. 2	196.7	q	Cushing Mon.	206.7	q	De Vinne No. 2	212.5	q	Ronaldson O.S.	217.5	q	Chelt. W.	219.2
r	Cushing No. 2	175.8	r	Ronaldson O.S.	181.7	r	Cushing Mon.	183.3	r	Chelt. O. S.	189.2	r	Della Robbia	190
s	Chelt. O. S.	138.3	s	Della Robbia	138.3	s	Ronaldson O.S.	141.8	s	Caslon O. S.	143.3	s	Cushing No. 2	145.5
t	Cushing No. 2	169.2	t	Cushing Mon.	179.2	t	Caslon O. S.	180.8	t	Chelt. O. S.	183.3	t	Jenson O. S.	188.3
u	Cushing Mon.	165	u	Cushing O. S.	175.8	u	Cushing No. 2	176.7	u	Chelt. O. S.	177.5	u	Jenson O. S.	180
v	Cushing No. 2	183.3	v	Caslon O. S.	180.8	v	Am. Typewr.	195	v	De Vinne No. 2	199.2	v	Chelt. O. S.	205
w	Am. Typewr.	183.3	w	Cushing No. 2	200.8	w	Cushing Mon.	233.3	w	Caslon O. S.	243.3	w	De Vinne No. 2	248.3
x	Cushing Mon.	155	x	Cushing No. 2	157.5	x	Chelt. O. S.	169.2	x	Ronaldson O.S.	170	x	Caslon O. S.	171.7
y	Cushing No. 2	194.2	y	Cushing Mon.	195.8	y	De Vinne No. 2	208.3	y	Ronaldson O.S.	210.7	y	Century Exp.	218.3
z	Cushing Mon.	143.3	z	Cushing No. 2	156.7	z	Cushing O. S.	157.5	z	Am. Typewr.	159.2	z	Caslon O. S.	162.5

TABLE XI. THE AVERAGE LEGIBILITY OF GROUPED LETTERS

THE NUMBERS IN THIS TABLE INDICATE THE AVERAGE DISTANCE AT WHICH EACH LETTER OF EACH FACE WAS READ. NINE FACES WERE SELECTED FOR THIS EXPERIMENT; AND ONLY LOWER CASE LETTERS WERE EMPLOYED. THE AVERAGES ARE COMPILED FROM 'INTERNAL' LETTERS ONLY, I. E., THE INITIAL LETTERS AND THE FINAL LETTERS OF THE GROUPS ARE NOT INCLUDED IN THESE AVERAGES

Bulfinch	Caslon	Century Exp.	Century O. S.	Cheltenham Wide	Cushing Monotone	Cushing O. S.	News Gothic	Scotch Roman
a 140	a 137	a 150	a 145	a 142	a 123	a 139	a 160	a 135
b 138	b 155	b 158	b 155	b 152	b 138	b 146	b 170	b 182
c 147	c 130	c 140	c 143	c 152	c 131	c 142	c 167	c 123
d 142	d 133	d 154	d 150	d 158	d 123	d 140	d 163	d 127
e 124	e 127	e 135	e 145	e 135	e 120	e 138	e 149	e 115
f 160	f 175	f 193	f 178	f 168	f 120	f 150	f 174	f 170
g 185	g 190	g 205	g 200	g 210	g 195	g 213	g 218	g 215
h 163	h 184	h 170	h 160	h 165	h 150	h 172	h 143	h 150
i 143	i 143	i 156	i 168	i 153	i 152	i 167	i 162	i 149
j 140	j 175	j 170	j 180	j 165	j 175	j 187	j 155	j 160
k 183	k 183	k 160	k 185	k 175	k 150	k 195	k 168	k 185
l 136	l 137	l 153	l 162	l 163	l 141	l 147	l 138	l 148
m 148	m 141	m 152	m 144	m 152	m 147	m 165	m 165	m 148
n 136	n 129	n 140	n 145	n 155	n 150	n 145	n 146	n 127
o 143	o 139	o 141	o 155	o 160	o 128	o 138	o 160	o 120
p 158	p 195	p 190	p 168	p 195	p 195	p 220	p 169	p 185
q 150	q 163	q 177	q 190	q 175	q 147	q 173	q 173	q 164
r 146	r 141	r 158	r 165	r 141	r 141	r 157	r 158	r 141
s 165	s 122	s 135	s 152	s 130	s 120	s 133	s 175	s 129
t 136	t 125	t 149	t 158	t 123	t 128	t 173	t 171	t 158
u 153	u 123	u 140	u 145	u 150	u 133	u 153	u 166	u 136
v 153	v 154	v 157	v 153	v 158	v 138	v 153	v 154	v 148
w 188	w 170	w 187	w 195	w 185	w 188	w 203	w 198	w 185
x 166	x 133	x 158	x 161	x 144	x 134	x 158	x 167	x 137
y 153	y 142	y 160	y 162	y 170	y 155	y 195	y 164	y 158
z 163	z 126	z 135	z 149	z 147	z 120	z 130	z 165	z 125
Aver. 150	149	159	162	159	144	163	166	151
	6	4	3	4	8	2	1	x

TABLE XII. THE RELATIVE LEGIBILITY OF GROUPED LETTERS

THE LETTERS IN EACH HORIZONTAL LINE OF THIS TABLE ARE ARRANGED IN DESCENDING ORDER OF LEGIBILITY—THE VERTICAL COLUMN AT THE LEFT CONTAINING THE MOST LEGIBLE ALPHABET. THE DATA FROM WHICH THIS TABLE WAS COMPILED DID NOT INCLUDE THE INITIAL LETTERS NOR THE FINAL LETTERS OF THE GROUPS

a	a	a	a	a	a	a	a	a
b	b	b	b	b	b	b	b	b
c	c	c	c	c	c	c	c	c
d	d	d	d	d	d	d	d	d
e	e	e	e	e	e	e	e	e
f	f	f	f	f	f	f	f	f
g	g	g	g	g	g	g	g	g
h	h	h	h	h	h	h	h	h
i	i	i	i	i	i	i	i	i
j	j	j	j	j	j	j	j	j
k	k	k	k	k	k	k	k	k
l	l	l	l	l	l	l	l	l
m	m	m	m	m	m	m	m	m
n	n	n	n	n	n	n	n	n
o	o	o	o	o	o	o	o	o
p	p	p	p	p	p	p	p	p
q	q	q	q	q	q	q	q	q
r	r	r	r	r	r	r	r	r
s	s	s	s	s	s	s	s	s
t	t	t	t	t	t	t	t	t
u	u	u	u	u	u	u	u	u
v	v	v	v	v	v	v	v	v
w	w	w	w	w	w	w	w	w
x	x	x	x	x	x	x	x	x
y	y	y	y	y	y	y	y	y
z	z	z	z	z	z	z	z	z

present in such a problem as this. The factors of size, of geometrical figure, and of heaviness or lightness of the lines which constitute the figure also play a part; and these two latter factors are neither constant nor uniform in their operation, as the reader may infer from an examination of the faces which are illustrated in Tables I, II, III, V, VI, VII, VIII, IX, X, XI and XII.

It is true that all of the letters employed in the investigation were printed in ten-point size. But the type-founder's unit of measurement refers to the size of the block of metal upon whose base the letter is cast, and not to the size of the letter itself. It is, of course, true that the size of the block of metal sets a limit which the size of the letter cannot exceed; but the size of the letter may be, and usually is, less than the size of the block of metal which supports it and which determines the number of 'points' which shall technically describe the size of the letter. Indeed, it is not unusual to cast, say, an eight-point letter upon a ten-point body; and a much greater difference between size of letter and size of body is possible, although greater divergences are neither customary nor commendable.

Hence, the fact that all of our letters are technically described as being of ten-point size does not guarantee that they shall all be of uniform width, nor even of uniform height. There are certain letters, the w's and the m's, which must, in the very nature of the case, be wider than others, the i's and the l's; and even the widths of the m and the w may vary, from face to face, if only the draughtsmen who design them choose to have it so. Nor are the heights of ten-point letters necessarily constant and uniform. Moreover, the lines which constitute the letter-form are themselves subject to variation; they may be faint, they may be heavy, they may be bold, they may contain both hair-lines and heavy lines, or they may contain lines of only one width or thickness throughout. Hence, any discussion of our results must consider the possible operation of three factors which may have to do with the legibility of letters: letter-form, size of letter, width of lines of letter. And when we come to the dis-

cussion of the results obtained from groups of letters, we shall see that yet a fourth factor—the extent of white margin around the letter—plays an important rôle.

A survey of Tables I, II and III shows that, as a matter of fact, all three variables are represented in the letters which were employed. But if, for the moment, we ignore these details, and seek to determine which of these sixteen faces, as actually employed in the art of printing, is the most readily legible when presented singly, we find an exceedingly interesting state of affairs.

Confining our attention first to the upper case letters, we discover that the Jenson face has a considerable lead over all of its competitors. The letters of the Jenson face were read, on the average, at a distance of approximately 282 cm., while the average for the sixteen faces is *ca.* 254 cm. The least legible face is American Typewriter,—which, indeed, is much less legible than any other face of the sixteen. The other fourteen faces fall into three groups. The most legible group contains (besides Jenson) Bulfinch, Century Oldstyle, Clearface, Cheltenham Oldstyle, Della Robbia, Century Expanded, News Gothic; Caslon Oldstyle, Cushing Oldstyle, DeVinne No. 2 and Ronaldson constitute the second group; while Cushing Monotone and Cushing No. 2 come next in order, with American Typewriter standing in a class by itself, as the least legible face.

Jenson was much less successful in designing a legible lower case face; his lower case characters are indeed scarcely more legible than the median of the sixteen faces. News Gothic proved to be the most legible of the lower case faces; and Cushing No. 2 is the least legible face of this series. Here the sixteen faces fall naturally into three groups: *1.* News Gothic, Bulfinch, Clearface, Century Oldstyle, Century Expanded and Cheltenham Wide; *2.* Jenson, Della Robbia, Cushing Oldstyle, Ronaldson Oldstyle, Cheltenham Oldstyle, DeVinne No. 2, American Typewriter and Caslon Oldstyle; *3.* Cushing Monotone and Cushing No. 2. The difference between the least legible face and the most legible face is much less in the lower case letters than in the upper

case letters,—twenty-one per cent. as compared with thirty per cent.

The briefest examination of the letters which were employed in our investigation is sufficient to show that they differ not only in their form, but also in their size, and in the thickness or heaviness of the lines which constitute them. In order to obtain a clearer insight into the relative significance of each of these variable factors as determinants of legibility, we made accurate measurements of the height and the width of certain lower case letters of each face, as well as of the breadth of the lines which go to make up the letters. Our measurements were made by means of a microscope which was equipped with a micrometer scale. Three letters, m, o and z, were selected for measurement; and it is assumed that the average size of these three letters, chosen from any face, may be regarded as being typical or representative of the relative size of all of the letters of the complete alphabet of the face to which they belong. In order to make it possible to institute a comparison between the size and the "blackness" or "heaviness" of any face of type, on the one hand, and its degree of legibility, on the other, the following table is appended. The first column contains the list of sixteen faces, arranged in order of legibility. The numbers in the second column indicate the average width, expressed in microns, of the m, o and z of the face whose name appears upon the same line in the first column; and the third column specifies the average height of the same three letters. The numbers in the fourth column indicate the thickness of the stem of the i of each face, also expressed in microns. Each number in the fifth column is obtained by multiplying the height of the letter by its width; each of these numbers may be assumed to represent the coefficient of area of a typical letter of each face. The numbers in the sixth column are obtained by multiplying the number which represents the area-coefficient by the number which represents the breadth of the principal lines which constitute the letter; these numbers in the sixth column may, therefore, be regarded as area-breadth coefficients which

TABLE XIII. ISOLATED LETTERS

SHOWING THE WIDTH AND THE HEIGHT OF LETTER, AND THE THICKNESS OF LINE, EMPLOYED IN THE VARIOUS FACES, AND THEIR RELATION TO LEGIBILITY.

	Wide	High	Thick	h×w	h×w×t	Average distance
1. News Gothic ...	1933	1982	333	3831	1277	236
2. Bulfinch	2033	1800	328	3659	1200	234
3. Clearface	1840	1750	333	3220	1073	230
4. Century O. S...	1944	1780	300	3460	1038	228
5. Century Exp...	1813	1766	300	3202	961	227
6. Cheltenham W..	1833	1420	317	2603	823	224
7. Jenson O. S....	1812	1560	317	2827	896	215
8. Della Robbia....	1757	1602	275	2815	774	214
9. Cushing O. S...	1553	1700	333	2640	880	213
10. Ronaldson O. S.	1613	1481	243	2389	580	209
11. Chelt. O. S....	1523	1440	316	2193	693	206
12. DeVinne No. 2..	1853	1510	450	2798	1259	205
13. Am. Typwr....	1544	1820	200	2810	562	202
14. Caslon O. S....	1611	1420	292	2288	668	202
15. Cushing Mon...	1471	1464	220	2154	474	191
16. Cushing No. 2..	1493	1480	200	2210	442	186

represent the relative size of letter and breadth of line which appear in the several faces.[6] Now an examination of the numbers in the fifth column shows that there is, in the upper part of the column at least, an approximate correlation between size of letter and degree of legibility. And when "heaviness" of line is also taken into consideration, as is done in the sixth column, one finds that the correlation is even more striking, for the first eight faces of the list. The fact that degree of legibility is correlated, at least in this approximate fashion, with size of letter and breadth of line

[6] The numbers in the fifth and the sixth columns are intended to represent relative magnitudes only. In order to facilitate comparison we have omitted several of the right-hand digits,—three from the numbers of the fifth column, six from the numbers of the sixth column.

of letter, leads one to suspect that, in these eight faces at least, the size of the letters and the amount of ink imprinted upon the paper by the lines of the letter were the chief determinants of legibility; and that such variants of letter-form as were represented in these eight faces played no essential part in determining the legibility of the letters.

The less legible faces of the list do not show such a perfect correlation. The lack of correlation is most evident in the case of DeVinne No. 2, which apparently should stand near the head of the list if size of letter and breadth of inked lines were the chief determinants of legibility. But it will be noticed that this face contains by far the heaviest lines of the series; and its relative illegibility is probably due to the fact that the optimal width of line is here exceeded, and that, in consequence, the white spaces within the letters have been encroached upon in so great degree as to promote illegibility. It would appear that the optimal breadth of line for lower case letters of this size may be in the neighborhood of 275 to 333 microns. It seems to be evident from our table that, when the breadth is reduced much below 250, or is increased in the neighborhood of 450, ten-point letters become relatively illegible.

It is scarcely possible, from the data at hand, to make any definite general statement regarding the relative significance of the three factors in question. Javal and others have insisted that the width of the letter is of prime significance as a determinant of legibility. And the fact that Cheltenham Wide, lower case, is read at an average distance of two hundred and twenty-four centimeters, while Cheltenham Oldstyle, which differs from the former scarcely at all save in its lesser width, is read only at two hundred and six centimeters, seems to confirm Javal's statement. But our experiments have convinced us that width of letter is but one of several factors which contribute to legibility; and one could assert with quite as much justice that the breadth of the lines which constitute the letter is the essential determinant of legibility. This latter statement, however, is true, if at all, only within relatively narrow limits.

The results which appear in Tables V and VI are of interest in this connection. Our experimental material here consisted of alphabets which represented a series of modifications of a given face. Cheltenham Oldstyle may be regarded as our standard face; Cheltenham Bold, Cheltenham Bold-Condensed, Cheltenham Wide and Cheltenham Italic represent modifications of our standard letter-form in the directions of greater heaviness of face, lesser width of letter-form, greater width of letter-form, and inclined or italic letter-form.

A survey of these results reveals the fact that legibility is very much increased by increased heaviness of face. In the upper case letters the increase in heaviness or breadth of line amounted to approximately forty-seven per cent., and the increase in legibility amounted to twelve per cent.; while in the lower case letters the corresponding data are forty-seven and fourteen per cent. When the Cheltenham Bold face is condensed by about twenty-three per cent., as is illustrated in the letters which appear in the third column of Table VI, its increase of legibility is lost,—being reduced by twelve per cent. This finding indicates that whatever advantage might have been derivable from increased heaviness of face, as compared with Cheltenham Oldstyle, is neutralized by a disadvantage which is due to a narrowing of the internal spaces within the letters, and a consequent sacrifice of detail. When the letter-form is broadened by eighteen per cent., its legibility is increased by nine per cent. The Italic letter-form proves to be but slightly less legible than the Roman face. In both the upper case and the lower case letters, the bold face is the most legible member of the series of modifications.

The data which are presented in Table IV show the relative legibility of each letter of the alphabet, both upper case and lower case, when presented as isolated letters. The numbers which appear in these columns represent the averages of the readings of the sixteen faces of each letter. The upper case letters are, of course, legible at a greater average distance from the observer than the lower case letters. But

the average legibility of both cases varies between wide limits; and it is a significant fact that certain of the latter letters are more legible than many of the former. The progressive decrease of legibility from the upper limit to the lower limit is fairly regular and uniform throughout, in both cases, with the exception of m and s. Indeed, our results show that the lower case s is by far the least legible letter of either alphabet. The upper case S also stands at the foot of its class, but the relative inferiority is here much less than in the lower case letter.

Any movement which plans to improve the forms of the letters of the alphabet must properly begin with the letters which appear in the lower half of this table. And, indeed, it might well confine itself, at the outset at least, to the lower case letters, for the twofold reason that they are, in general, less legible than upper case letters and are therefore most in need of reformation, and that our reading has to do, in the main, with the recognition of words which are composed of lower case letters exclusively. It is not the purpose of this paper to recommend or even to suggest the procedure by means of which an increased legibility of printing types is to be attained. But it may, at least, be mentioned in passing that letters are made more legible by an increased heaviness of printing-face; and that defective letters may be made more legible by simply extending their width. Both of these innovations would meet with opposition, however, from those readers who demand aesthetic beauty and grace of form as well as legibility. But it seems possible that all demands could be met and all interests could be safe-guarded if only sufficient skill and ingenuity were devoted to the task.

B. GROUPED LETTERS

The object of this part of the investigation was to determine how and to what extent the legibility of letters is affected by the presence of adjacent letters. It was to be expected that the isolated letter should possess an advantage over the member of the letter-group in point of average distance at which reading is possible. Is the disadvantage which

results from grouping equally great for each face? What is the relation between legibility and position (initial, final, intermediate) within the group of letters? What light is thrown upon our problem by the number and the nature of the misreadings or confusions which are due to the grouping of letters?

Isolated letters are invariably read at a greater average distance than are those letters which occur in groups. Among our material were eight faces which had been employed in both of our series of experiments, *i. e.*, they had been presented singly in the earlier experiments,—grouped in the later experiments. It is therefore possible to make a direct comparison between the degrees of legibility which were revealed under these two conditions. (The Scotch Roman face can not be included in making this comparison, because it was employed only in the later series of experiments.) The average distance at which these eight faces were read in the earlier experiments was 232 cm.; in the later experiments, 157 cm. The varying degrees of legibility tend to be reduced to a common level as a result of grouping, *i. e.*, differences in the legibility of different faces tend now to disappear. While the legibility of the eight faces, presented as single letters, varied between the limits 191 cm. and 236 cm., they varied only between the limits 144 cm. and 166 cm. when presented in groups. And the general reduction of legibility was so great that the most legible face of grouped letters proved to be wholly undecipherable at a distance where the least legible face of isolated letters was clearly and unmistakably legible.

The gross results of the experiments with grouped letters are presented in Table XI. The average distances are tabulated in more significant form in Table XIII, which also contains a statement of the relation between decreased legibility and size-heaviness of face.

News Gothic is still the most legible face, and Cushing Monotone the least legible. Century Oldstyle, Century Expanded, Cheltenham Wide and Caslon also maintain the same positions in the series which they held when isolated letters

were employed. But Cushing Oldstyle, which occupied the sixth position in the former series, now moves up to the second position; and Bulfinch drops from the second to the sixth position. Scotch Roman, the face which had not been tested in the first part of the investigation, stands seventh in descending order of legibility.

Cushing Oldstyle and Bulfinch are the only faces which show any decided loss or gain in relative legibility, when submitted to the group-test. But one is led to inquire why even these two faces should fail to maintain the same degree of relative legibility when presented in groups which they established when presented as isolated letters.

A comparison of the amounts of reduction in legibility which the various faces suffered from being grouped reveals the fact that these amounts vary from twenty-three per cent. to thirty-seven per cent. It is inevitable that certain faces should be subject to a relatively great disadvantage as a result of being combined into groups, and from being printed "solid," as upon the body of an unleaded page. The letters of certain faces are so wide and so high that a comparatively narrow margin is left upon the block of metal which constitutes the body of the type, while in other faces the margin is relatively wide. For example, our measurements show that the Bulfinch m is 2560 microns in width and 1828 microns in height, while the corresponding measurements of the Cheltenham Oldstyle m are 1948 and 1440 microns. Variations in width of letter need not be considered here, because there need be no corresponding variations of width of blank space between adjoining letters upon the printed page. But the difference in height between the letters of these two faces is so great that adjacent lines of the two, if set "solid," would show an intervening space of white paper which would be 380 microns wider in the case of Cheltenham than in the case of Bulfinch. It follows then that while the ten-point letters of greatest average height are most legible when presented singly,—because they subtend a larger visual angle, —they tend to lose their advantage when combined into groups and lines,—because the lines are separated from one

another by narrower intervening spaces of white; and the reader finds that the letters of adjoining lines tend to merge into one another.

The effect of breadth of interlinear space could be shown quantitatively by correlating the average height of each face with the relative amount of decrease in legibility which it suffers as a result of grouping. It would then be found that those faces whose average height is greatest have suffered most from being presented in groups, while those faces whose average height is least have suffered least. The correlation becomes more striking however when thickness of line as well as height of letter is taken into account. But even here, News Gothic and Cushing Old Style appear to be exceptions to the general rule.

Now it is a remarkable fact that these two types are by far the heaviest faces of the series. In selecting an arbitrary method of giving quantitative expression to the combined influence of the factors of size of letter and of heaviness of line, in order that seriation and comparison might thereby be facilitated, we have chosen to multiply the height of the letter by the thickness of the line. It is evident, however, that these two factors are wholly different in their mode of operation and in their relation to legibility. The legibility of a face undoubtedly increases directly with the increase in the size of the face; and the ratio between the two is capable of simple quantitative expression. But the relation between legibility and heaviness of face is far from being a simple one. Beginning with the faintest monotone, legibility increases with increase of thickness of line until an optimal thickness of line, for a given size of letter, is reached; from that point onward legibility decreases with increase of thickness of line, because now the internal details of a, c, e, o, etc., are being narrowed down to mere points, and discrimination of detail soon ceases to be possible. We are not in possession of any data which furnish a basis for estimating the point at which the optimal thickness of line is reached, nor for estimating the relative significance of size of letter and thickness of line. And until such data are obtained it will remain

impossible to seriate the numbers in the fifth column in any just or appropriate fashion.

Our results, however, indicate that the variations of letter-form which were present in our nine faces did not vary between sufficiently wide limits to have any considerable effect upon the relative legibility of our letters. Such differences of legibility as were revealed are, we believe, referable solely to variations in size of letter (and of interlinear space), and to variations in heaviness of face.

If legibility is to be our sole criterion of excellence of type-face, News Gothic must be regarded as our nearest approximation to an ideal face, in so far as the present investigation is able to decide this question. The aesthetic factor must always be taken into account, however, here as elsewhere. And the reader who prefers the appearance of Cushing Oldstyle or a Century face may gratify his aesthetic demands without any considerable sacrifice of legibility.

An examination of our records of the misreadings of letters throws an interesting light upon the question of similarities of letter-form, and upon the question of the criteria employed by the reader in deciphering letters. When the letters first appeared at or beyond the extreme limit of reading distance, the reader was usually conscious, from the outset, of a more or less definite *Einstellung*. If they were lower case letters, and especially if they were presented in isolated form, the reader first set out upon a more or less definite search for the "broad" letters,—m and w. He seldom failed to discover these two letters in the earlier stages of the settings of the carriage, although he was seldom able to discriminate between m and w until the carriage had been brought nearer to his eye. His next endeavor was to find the "narrow" letters, —i, l, j; another category was "letters which are wider at the top than at the bottom,"—v, r; V, Y, T, F, P. Here again he almost invariably succeeded in referring the letter-form to its appropriate category some little time before he was able to distinguish its details and name it with any degree of certainty. Other general groups were "circular

letters,"—o, e, c; O, C, G, Q; "square letters,"—H, K, E, B, D. Among the lower case letters, "ascenders" and "descenders" were almost invariably recognized as such, before their details became clear. While the reader was still struggling with one or other of these categories, the "unclassified" letter-form began to emerge in an order which can not well be formulated in a general statement.

This description of the reader's procedure indicates the type of confusion or misreading which proved to be most frequent. Letters which may be regarded as members of a common category were especially likely to be confused with one another; r, v; o, c, e; x, z; u, n; b, h, k; q, y; i, l, j, t, f; M, W; H, K, E, B, D; O, Q, C, G; V, Y F T; I J, L.

Several wholly new types of misreadings made their appearance when the letters were presented in groups. These may be described as 1. Combinations, 2. Separations, and 3. Elisions. 1. It frequently happened that adjoining letters were blended together by the reader, and that a single letter was constituted by this combination of parts, or wholes, of different letters, thus: lc (k); ls (k); lx (k); li (h); cl (d); cf (d); un (m); in (m); vr (w); js (p); vj (y); cj (q); hj (ly); bj (lq); chn (dm); ck (dx). 2. The separation of letters into their parts has been illustrated in the above group. It also ocurred in such cases as wm (vun); ld (bl); bj (lq); hj (ly); kd (hcl). 3. Perhaps the most striking misreading was due to the complete elision of certain letters of the group. This phenomenon was especially common with such slender or narrow letters as i, j, t, r, v, s. When i or t was interpolated between ascending letters, when j occurred between descenders, and when r and s were present in any context of whatever sort, they were likely to be wholly overlooked. And it frequently happened in such cases that the observer read and reread the group of letters, specifying correctly every letter which was present excepting these narrow letters. When the carriage had been brought so close to his eye that he finally detected their presence, he usually

expressed surprise that these "indifferent" letters had escaped detection so long.

The position of the letter in the group—initial, final, intermediate—is an important factor in determining the legibility of the letter. When a group of letters first comes into view, it almost invariably happens that certain of the letters stand out more prominently than their neighbors. The part which these "dominating" letters play in our recognition of familiar words has been discussed at length by Zeitler, Messmer, and others, who have pointed out that the rôle of the "indifferent" letters in our recognition of familiar words is relatively insignificant. Pillsbury and others have shown that, all other conditions being equal, the initial letter or letters in the word are of most significance in the act of reading.

In compiling the results obtained from the reading of our letter-groups, we have made three distinct tables of data,—for the initial letters, for the final letters and for the intermediate letters of the groups. The latter results have already been presented, in Tables XI and XII. A comparison of these three series of average distances shows that the initial position constitutes an optimal condition of legibility; the final position comes next in order, and the intermediate position is least favorable,—the general averages being 196 cm., 185 cm., and 156 c., respectively.

It must, of course, be borne in mind that all intermediate positions are not equally disadvantageous, because the form of the adjacent letters is really an essential factor which aids or hinders legibility. For instance, an m which stands between u and n is much less legible than an m which stands between o and c; and the helpful or harmful influence of ascending and descending letters is also very great. The significance of the initial position or the final position is also subject to variation. It is evident, for instance, that those letters whose "loop" is upon the right,—b, h, p,—will derive more benefit from appearing in the final position than will those letters whose "loop" is upon the left,—d, q, Yet the superior advantage of the initial position is so great that

b, h, and p frequently proved to be read at a greater distance when they appeared as initials than when they appeared as final letters, notwithstanding the fact that the characteristic parts of these letters appeared in close proximity to a neighbor in the former case, while in the latter case they jutted out into the blank spaces between the groups.

Lower case c was read at the following average distances: Initial 155 cm., final 163 cm., intermediate 144 cm. The corresponding data for several other letters are: e, 140, 147, 123; o, 158, 153, 143; b, 187, 198, 155; d, 200, 165, 143; h, 185, 200, 162; k, 195, 198, 176; p, 201, 207, 186; q, 209, 194, 168; f, 196, 202, 176. The "symmetrical" letters show, in more accurate quantitative form, the relative advantages of the initial and the final positions; v, 185, 172, 152; o, 158, 153, 143; m, 163, 156, 151; w, 210, 199, 189.[7]

The Relation Between Legibility and Quality of Paper-Surface

As already indicated, our groups of letters were printed in duplicate upon a coated book-paper, and upon an antique laid book-paper. A comparison of the average distances at which the letters were read under these two conditions should throw light upon the general question as to the dependence

[7] The reader is again warned that these data do not warrant a comparison as to the relative legibility of different letters of the alphabet. The writer does not guarantee that the juxtapositions of letters which occurred in our groups were equally disadvantageous for all of the letters of the groups. It is obviously an exceedingly difficult task to so arrange a series of groupings that all of the letters in the groups will be treated with even-handed justice in so far as advantageous and disadvantageous collocation with their neighbors is concerned. A juxtaposition which is relatively advantageous to l or h may be relatively disadvantageous to o or v. This condition we could not hope to fulfil; our aim was rather to treat all of the faces with equal fairness,— to present no combination of letters of one face which did not recur in the letters of every other face; our data therefore warrant a comparison of the relative legibility of the various faces, but not of the relative legibility of the various individual letters of the same or different faces.

of legibility upon the quality and texture of paper employed by the printer.

This question has been raised in various forms, in the history of the art of printing. Many years ago Babbage recommended the use of slightly yellowish paper for the manufacture of books; and indeed, he succeeded in persuading a publisher to produce a book of logarithms in accordance with this recommendation. More recently Javal has advocated a similar innovation, urging that such a plan would minimize the disadvantage to which the reader is subjected on account of the intensive contrast between the black ink and the white paper which are in general use.

It is impossible, from data available in the literature of this and cognate topics, to determine whether this Babbage-Javal suggestion is really of value. But such results of the present investigation as have a bearing upon the question would seem to indicate that little or no improvement of legibility is to be expected from progress in this direction.

The results which we obtained in those experiments which consisted in presenting groups of letters of nine faces which had been printed upon coated white paper and rough-finished, very slightly yellowish paper, show a surprisingly slight difference of legibility in the two cases. The average distance at which the letters were read in the former case was 144.9 cm., and in the latter case, 145.0 cm. Altogether 234 letters were employed in these experiments, and 2,808 readings were taken. The experimental conditions were identical in the two cases, excepting the difference in the quality, the color and the texture of the paper upon which the letters were printed. Occasionally we found individual differences among our observers,—a greater efficiency when a particular face of type appeared upon the one or other of the papers; but in not a single instance does the individual difference in legibility amount to more than three per cent.; and in no instance did we find a unanimous preference of either paper with any face of type. Not only then are the individual variations so slight as to be negligible, but they are so irregular and inconstant as to be subsumable under no general principle. And the

only conclusion which they warrant is that even such a considerable difference as was represented in our two papers has little or no significance for legibility.

V. CONCLUSIONS

1. Certain faces of type are much more legible than other faces; and certain letters of every face are much more legible than other letters of the same face.
2. These differences in legibility prove to be greater when letters are presented in isolation from one another than when they are presented in groups.
3. Legibility is a product of six factors: *1.* the form of the letter; *2.* the size of the letter; *3.* the heaviness of the face of the letter (the thickness of the lines which constitute the letter); *4.* the width of the white margin which surrounds the letter; *5.* the position of the letter in the letter-group; *6.* the shape and size of the adjacent letters. In our experiments, the first factor seemed to be less significant than any of the other five, *i.e.*, in the type-faces which were employed in the present investigation, the form of any given letter of the alphabet usually varied between such narrow limits as to constitute a relatively insignificant factor in the determination of its legibility.
4. The relatively heavy-faced types prove to be more legible than the light-faced types. The optimal heaviness of face seems to lie in a mean between the bold faces and such light faces as Scotch Roman and Cushing Monotone.
5. The initial position in a group of letters is the most advantageous position for legibility; the final position comes next in order of advantage, and the intermediate or internal positions are least favorable for legibility.
6. The size and the form of the letters which stand adjacent to any given letter play an important rôle in determining its legibility; and the misreadings which occur in the case of grouped letters are of a wholly different sort from those which occur in the case of isolated letters.

When letters of the same height or of similar form appear side by side, they become relatively illegible. But the juxtaposition of an ascender, a descender and a short letter tends to improve the legibility of each, as also does the juxtaposition of letters which are made up wholly or chiefly of straight lines, and letters which are made up wholly or chiefly of curved lines.

7. The quality and the texture of the paper is a much less significant factor than has been supposed,—provided, of course, that the illumination and the inclination of the paper are such as to secure an optimal condition of light reflection from its surface.
8. There is an urgent need for modification of certain letters of the alphabet.

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